NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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INVESTIGATION OF THE AILERON AND TAB OF A SPRING-TAB LATERAL-CONTROL SYSTEM IN THE LANGLEY 19-FOOT PRESSURE TUNNEL

By Owen J. Deters and Robert T. Russell

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

Tests of a partial-span model of a large bomber-type airplane were conducted to provide data on the aerodynamic characteristics of the aileron-tab arrangement and of the wing. The aileron-tab arrangement included a 20-percent constant-percentage-chord aileron having a 54-percent internally sealed aerodynamic balance and a constant-chord tab of approximately 26-percent of the average aileron chord over the span of the tab. Tests were made to determine the rolling-moment, yawing-moment, and hinge-moment characteristics of the aileron and tab and the effect of midchord wing slots on the characteristics of the wing and aileron and tab.

The midchord wing slots located ahead of the aileron improved the maximum lift and stalling characteristics, increased the rolling effectiveness at high angles of attack, but impaired the aileron effectiveness and hinge-moment characteristics at low angles of attack.

As the angle of attack was increased, the effectiveness of the internal balance was reduced and the aileron hinge-moment coefficients became more negative and produced a large upfloating tendency of the ailerons.

At small positive aileron deflections, the tab was stalled at negative tab deflections in excess of 10° at low angles of attack and at negative tab deflections in excess of 15° at high angles of attack.

Leakage around the tab hinge caused a decrease in the effectiveness of the tab at low angles of attack, but had little effect at high angles of attack.

INTRODUCTION

The problem of providing satisfactory airplane control forces becomes increasingly difficult as the size and speed of airplanes increase. The maximum allowable control force is fixed within the capabilities of the pilot, whereas the control hinge moments, which must be overcome by pilot effort, increase as the square of the speed and as the cube of the airplane linear dimension. Thus, as the airplane increases in size, an increasingly greater percentage of the control hinge moments must be balanced in order to maintain the control forces within the capabilities of the pilot. Closely balanced controls, however, have a disadvantage in that overbalance may result from variations in surface conditions or construction irregularities. The spring-tab type of control system is one in which the amount of balancing action contributed by the spring tab is dependent upon the force exerted by the pilot. This system has the advantage that the control cannot be overbalanced as a result of the balancing action of the tab. Thus by combining the spring tab with a form of aerodynamic balance a closely balanced control can be obtained without the danger of overbalance.

Much data have been published concerning the effect of tabs on the characteristics of the wing and aileron. Comparatively little data, however, are available concerning tab hinge-moment characteristics, which are important in spring-tab control systems.

The results are presented herein of an investigation of a spring-tab-type lateral control system for a large bomber-type airplane conducted in the Langley 19-foot pressure tunnel. The tests were made to determine the rolling-moment, yawing-moment, and hinge-moment characteristics of the aileron and tab and the effect of midchord wing slots on the characteristics of the wing and aileron and tab. Also included were tests to determine the effect of leakage around the tab hinge on the characteristics of the aileron.

COEFFICIENTS AND SYMBOLS

The measured aerodynamic forces and moments were reduced to standard nondimensional coefficients and corrected so that all coefficients presented herein apply to the complete wing. The pitching-moment, rolling-moment, and yawing-moment coefficients apply to a center-of-gravity location 25 percent of and 5 percent below the mean aerodynamic chord in the plane of symmetry.

The coefficients and symbols used are defined as follows:

C_L	lift coefficient (L/qS)
C_D	drag coefficient (D/qS)
C_m	pitching-moment coefficient (M/qSc')
C_l	rolling-moment coefficient (L'/qSb)
C_n	yawing-moment coefficient (N/qSb)
C_{h_a}	aileron hinge-moment coefficient $\left(H_a/qb_a\bar{c}_a^{\,2}\right)$, positive when tending to produce a more positive aileron deflection
C_{h_t}	tab hinge-moment coefficient $\left(H_t/qb_t\bar{c}_t^{\,2}\right)$, positive when tending to produce a more positive tab deflection
L	lift
D	drag
M	pitching moment
L'	rolling moment
N	yawing moment
H_a	aileron hinge moment
H_t	tab hinge moment
q	dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$
b	wing span
S	wing area
c'	mean aerodynamic chord
c	wing chord
c_a	aileron chord
$b_a\bar{c}_a^{\,2}$	product of aileron root-mean square chord squared and aileron span

$b_t\bar{c}_t^2$	product of tab root-mean-square chord squared and tab span
V	airspeed
a	velocity of sound
ρ	mass density of air
μ	viscosity of air
α	angle of attack of root chord, degrees
δ_f	flap deflection, degrees
δ_a	aileron deflection, degrees, positive when trailing edge is moved down
δ_t	tab deflection, degrees, positive when trailing edge is moved down
R	Reynolds number $(\rho Vc'/\mu)$
M	Mach number (V/a)

APPARATUS AND TESTS

Model and Installation

The model simulates the outboard 94.6 percent of the left wing of the airplane. The arrangement of the model with respect to the tunnel and the principal dimensions of the model are shown in figures 1 to 3.

A small gap (0.09 ±0.03 in.) was maintained constant between the wing and reflection plane by an automatic telescoping section in the root end of the model. The automatic mechanism was inoperative for some of the tests for maximum lift and aileron characteristics, during which the gap varied from 0.09 to approximately 0.25 inch. It is not believed that this increase in the gap produced any appreciable effect on the characteristics of the wing and aileron. The aerodynamic forces and moments of the wing model were measured by means of a six-component simultaneously recording balance system. The hinge moments of the aileron and tab were measured by means of cantilever-beam-type electric strain gauges.

Wing.- The wing model was not a true semispan but represented that part of the wing outboard of the wing-fuselage juncture. The aspect and taper ratios for the airplane wing are 11.09 and 0.25, respectively, whereas the semispan model mounted in conjunction with the reflection plane simulated a wing of aspect ratio 10.84 and taper ratio 0.25. The quarter-chord line of the wing was swept back 12.15°. The airfoil sections were the NACA 63(420)-422 at the root, and at the tip the NACA 63(420)-517. The wing model had 2° dihedral and 2° aerodynamic washout.

Aileron and tab.- The aileron was a 20-percent constant-percentage-chord aileron having a 54-percent internally sealed aerodynamic balance. The hinge line was located near the upper surface of the aileron as shown in figure 4. The aileron extended from the outboard nacelle to the wing tip, approximately 40 percent of the complete wing semispan. The lower-surface trailing-edge cusp, normally present in the contour of NACA 6-series airfoil sections of the type employed for the present tests, was removed by fairing a straight line between the 80-percent-chord station and the trailing edge. The aileron tab is shown in figures 3 and 4. The tab had a constant chord length of approximately 26 percent of the average aileron chord over the span of the tab.

Wing slots.- The principal dimensions and geometry of the mid-chord wing slots ahead of the aileron are shown in figure 5. The slots are normally closed with flaps retracted and open with flaps deflected.

Wing flaps.- The model was equipped with two types of partial-span wing flaps, single slotted and double slotted, as shown in figures 6 and 7. The flaps extended from the inboard end of the model (the wing-fuselage juncture) to the outboard nacelle. The flaps consisted of three segments separated by the inboard and center nacelles.

Test Conditions

The dynamic pressure for the tests was approximately 105 pounds per square foot, which corresponds to a Reynold's number of approximately 8,900,000 and a Mach number of approximately 0.18. The density of the atmosphere was maintained at approximately 0.0050 slug per cubic foot. The angle of attack varied from -4° through maximum lift; the range of deflections for the aileron and tab were -24° to 17° and -20° to 20°, respectively.

CORRECTIONS AND ACCURACY

The corrections to the measured values of the aerodynamic characteristics were determined by the methods of reference 1 and the magnitude of the individual corrections are as follows:

$$C_D = C_{D_{uncorrected}} + 0.0148{C_L}^2$$

$$\alpha = \alpha_{uncorrected} + 0.926C_L$$

$$C_m = C_{m_{uncorrected}} + 0.0344C_L$$

$$C_l = 0.814\left(C_{l_{uncorrected}} - C_{l_{tare}}\right)$$

$$C_n = C_{n_{uncorrected}} - C_{n_{tare}} - 0.0410C_l C_L$$

The absolute values of lift, drag, and pitching-moment coefficient are not correct inasmuch as no corrections were applied for the tare and interference effects of the support-strut system. Incremental values of all coefficients are considered to be correct as well as the absolute values of rolling-moment, yawing-moment, and hinge-moment coefficients. The accuracy of the test data presented herein was believed to be as follows:

ΔC_L	±0.01
ΔC_D	±0.0002
ΔC_m	±0.003
C_l	±0.001
C_n	±0.0005
C_{h_a}	±0.003
C_{h_t}	±0.003
α, degree	±0.1
δ_a, degree	±0.15
δ_t, degree	±0.5

RESULTS AND DISCUSSION

Aerodynamic and Stalling Characteristics of the Wing

Flap and slot effectiveness.- The effect of various configurations of slots and flaps are presented in figure 8. There were no abnormal effects produced on the aerodynamic characteristics as a result of deflecting either single slotted or double slotted flaps.

The effect of opening the slots was as follows: At large angles of attack the lift coefficient was increased, the drag coefficient was decreased for a given lift coefficient, and the slope of the pitching-moment-coefficient curve became more negative. At small angles of attack the effects were reversed; the lift coefficient was reduced, the drag coefficient for a given lift coefficient was increased, and the slope of the pitching-moment-coefficient curve became less negative.

Stalling characteristics.- In all configurations with slots open (fig. 9) the general progression of the stall was from the outboard nacelle toward the root; however, some regions of the aileron remained stalled through most of the angle-of-attack range. With slots closed the stall enveloped the aileron before maximum lift was reached and progressed inboard for all flap configurations. With single slotted flaps deflected 40° the root remained unstalled until very high angles of attack. Opening the slots caused rough and stalled flow over the aileron at low angles of attack; however, at high angles of attack the flow over the aileron was considerably improved over that with slots closed. The slots were effective in preventing a complete stall over the ailerons at high angles of attack.

Aerodynamic Characteristics of the Aileron and Tab

At high angles of attack the ailerons had a large tendency to float upward as shown in figure 8. In an attempt to correct this upfloating tendency various lower-surface modifications were made to the aileron and tab. The modifications consisted of a bevel along the lower surface of the aileron trailing edge and bulb on the lower surface of the tab. In a spring-tab aileron system any upfloating tendency would cause the ailerons to deflect upward unless the ailerons were interconnected or sufficient preload of the spring units was provided. By use of the lower surface modifications the loads on the interconnecting link (ailerons interconnected) might be effectively reduced or the amount of spring preload required could be greatly decreased when the ailerons were not interconnected. Although the modifications caused a reduction in the upfloating tendency at high angles of attack the lower surface bevel produced a large increase in the downfloating tendency at low angles of attack and caused the ailerons to be severely overbalanced; and the lower surface bulb caused very erratic aileron hinge-moment characteristics when the tab was deflected. Because of these unsatisfactory characteristics the lower surface modifications did not provide a practical means of correcting the upfloating tendency of the ailerons and therefore the data are not presented.

Aileron characteristics.- The characteristics of the aileron for various angles of attack and flap and slot configurations are presented in figures 10 to 12. With flaps neutral and deflected, the aileron was slightly overbalanced at low angles of attack. As the angle of attack increased the effectiveness of the internal balance was reduced and the aileron hinge-moment coefficients became more negative and produced a large upfloating tendency of the ailerons.

The effect of deflecting the single slotted flaps is to increase the negative aileron hinge-moment coefficients at high angles of attack, the general characteristics of the curves remaining unchanged. The effect of the flaps on the tab hinge-moment coefficients is similar to that on the aileron hinge-moment coefficients. With flaps deflected, the ailerons produced slightly smaller adverse yawing-moment coefficients, an increase in the rolling-moment coefficients at negative deflections, and a decrease at positive deflections.

The effect of opening the slot was to impair the hinge-moment characteristics at low angles of attack and to reduce the negative aileron hinge-moment coefficients at a given angle of attack. The tab hinge-moment characteristics are affected in a similar manner. The yawing-moment coefficients became more adverse and the rolling effectiveness was increased at high angles of attack but reduced at low angles. These undesirable effects at low angles of attack are the result of stalled flow over the aileron caused by opening the slot (fig. 9).

There was no appreciable change in the characteristics of the aileron as a result of the deflection of double slotted rather than single slotted flaps.

Tab characteristics.- The characteristics of the tab are given in figure 13 with flaps neutral, and in figure 15 with flaps deflected and slots open. In both flap configurations the effectiveness of the tab was slightly greater for small negative deflections than at any point in the range of tab deflections. At small positive aileron deflections the tab was stalled at negative deflections in excess of 10° at low angles of attack and at negative tab deflections in excess of 15° at high angles of attack.

Although the tab was effective in reducing the aileron hinge-moment coefficients, a loss resulted in the effectiveness of the aileron. The reduction in aileron effectiveness due to deflection of the tab varied directly in every instance with the ability of the tab to reduce the aileron hinge-moment coefficients.

The effect of sealing the tab is shown by a comparison of figures 13 and 14 (flaps neutral) and 15 and 16 (flaps deflected). In both flap configurations the tab seal produced an increase in the effectiveness of the tab at low angles of attack, particularly at the high aileron deflections. At high angles of attack the effect of the tab seal was greatly reduced although the sealed tab remained more effective than the unsealed tab.

As with the tab unsealed, the reduction in aileron effectiveness due to deflection of the tab varied directly in every instance with the ability of the tab to reduce the aileron hinge-moment coefficients. No change in the yawing-moment coefficients resulted from sealing the tab.

SUMMARY OF RESULTS

The significant results of the tests of the partial-span wing model may be summarized as follows:

1. Midchord wing slots located ahead of the aileron improved the maximum lift and stalling characteristics, increased the rolling effectiveness at high angles of attack, but impaired the aileron effectiveness and hinge-moment characteristics at low angles of attack.

2. The effectiveness of the internal balance was reduced as the angle of attack was increased and the aileron hinge-moment coefficients became more negative and produced a large upfloating tendency of the ailerons.

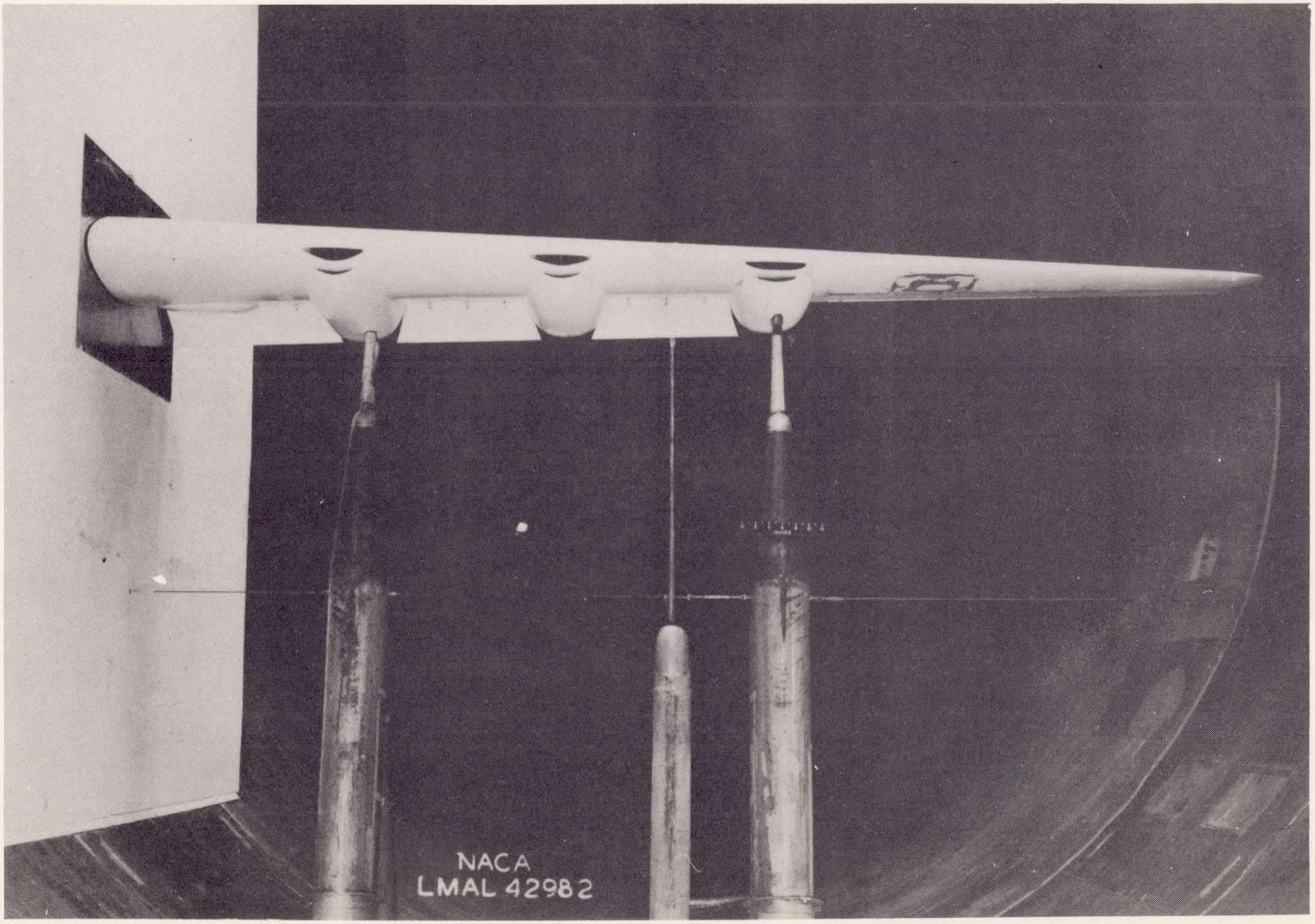
3. At small positive aileron deflections, the tab was stalled at negative tab deflections in excess of 10° at low angles of attack and at negative tab deflections in excess of 15° at high angles of attack.

4. Leakage around the tab hinge caused a decrease in the effectiveness of the tab at low angles of attack but had little effect at high angles of attack.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 19, 1947

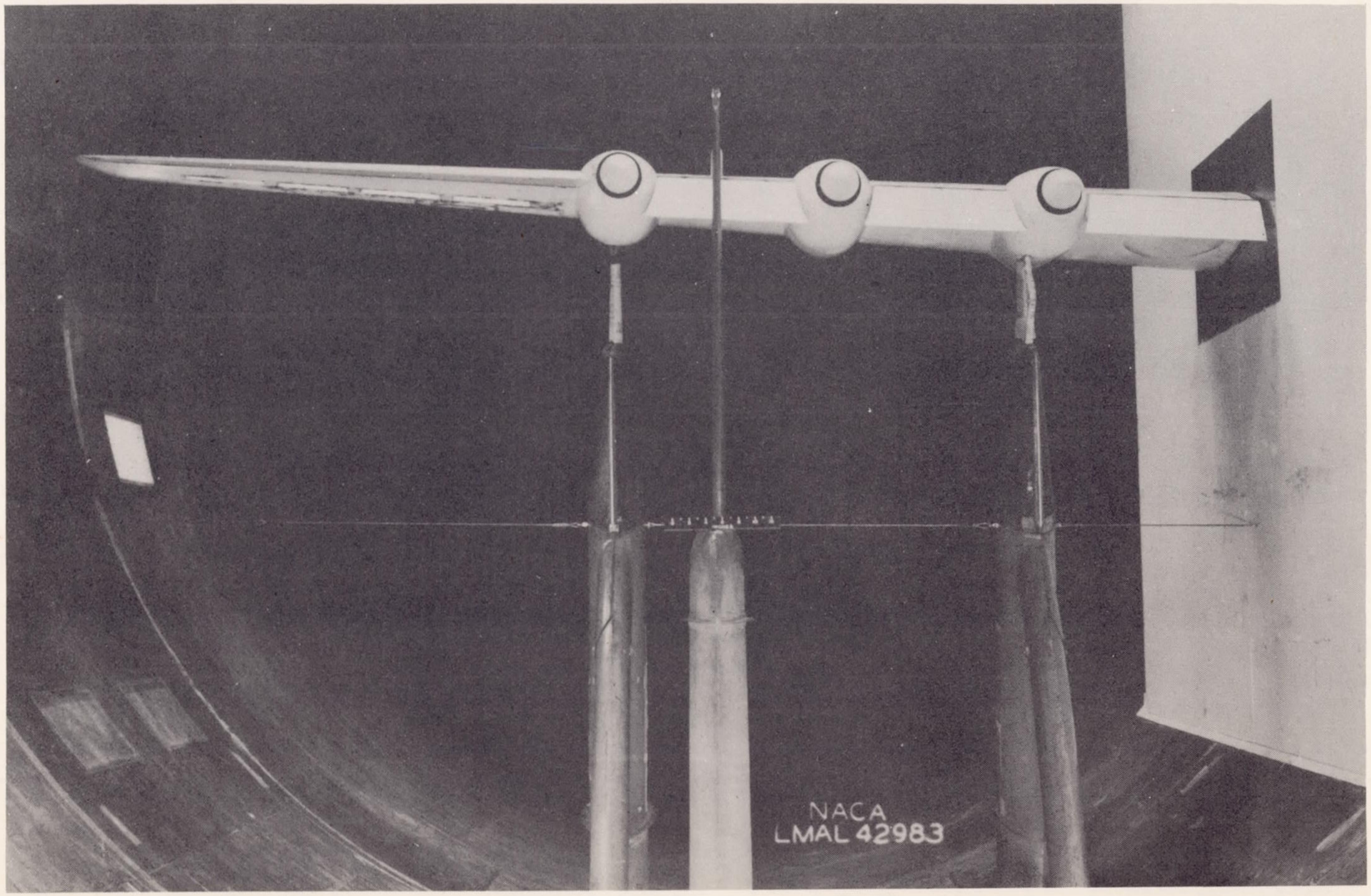
REFERENCE

1. Sivells, James C., and Deters, Owen J.: Jet-Boundary and Plan-Form Corrections for Partial-Span Models with Reflection Plane, End Plate, or No End Plate in a Closed Circular Wind Tunnel. NACA TN No. 1077, 1946.



(a) Front view.

Figure 1.- The reflection-plane and partial-span wing model mounted in the Langley 19-foot pressure tunnel.



(b) Rear view.

Figure 1.- Concluded.

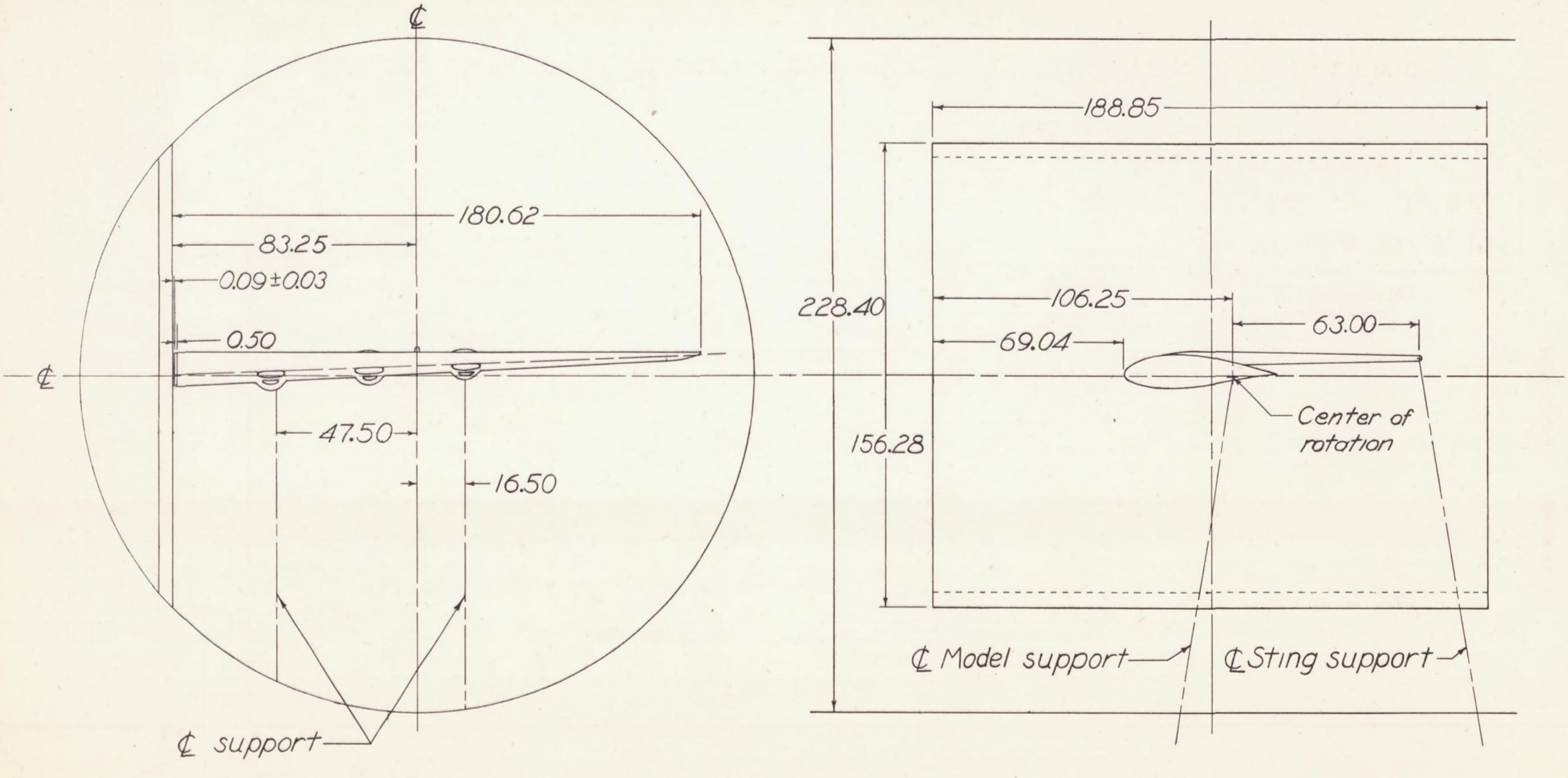


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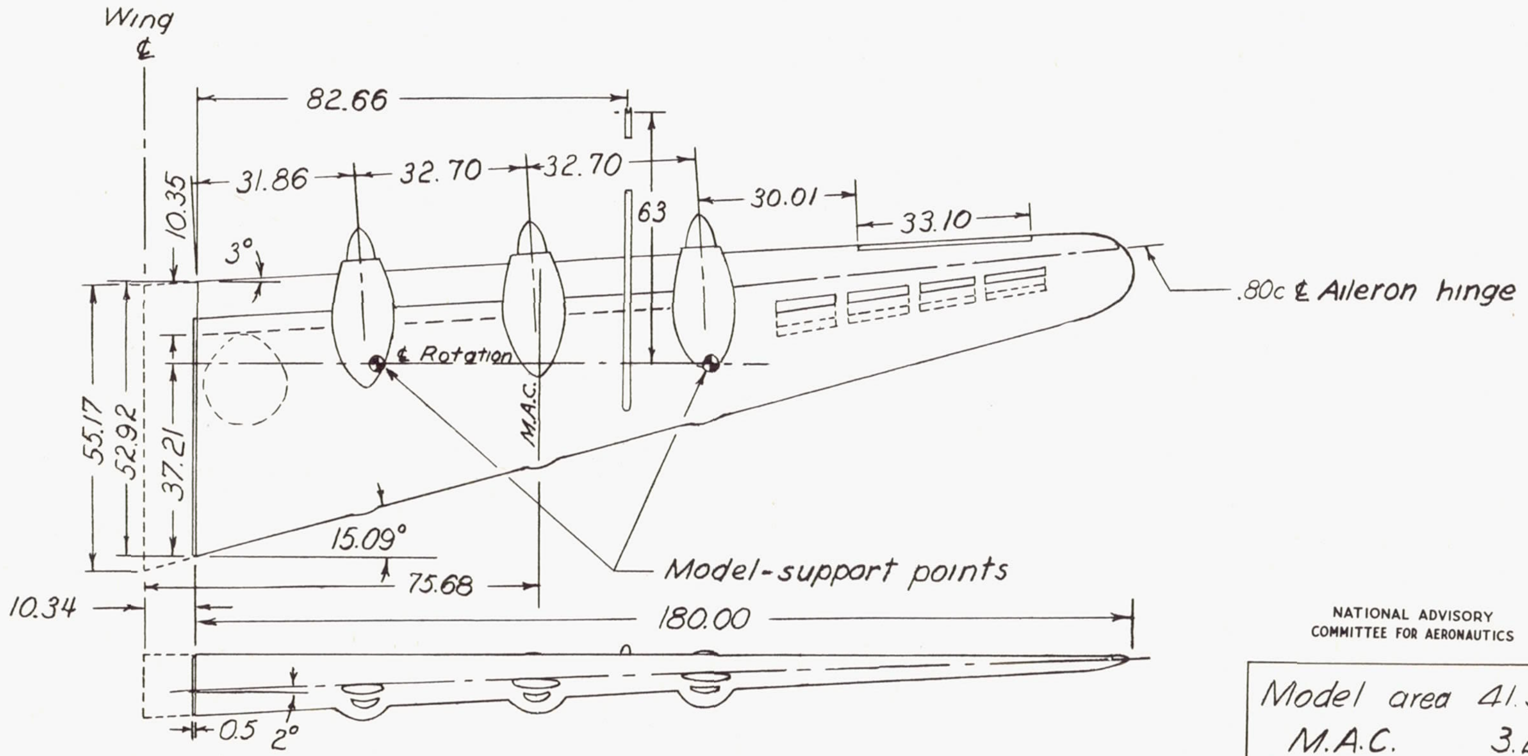
Figure 2.- Arrangement of the partial-span wing model and reflection plane in the Langley 19-foot pressure tunnel. (All dimensions in inches.)



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Model area 41.51 ft^2
M.A.C. 3.23 ft
(Complete wing)

Figure 3.- Plan and elevation of the partial-span wing model. (All dimensions in inches.)

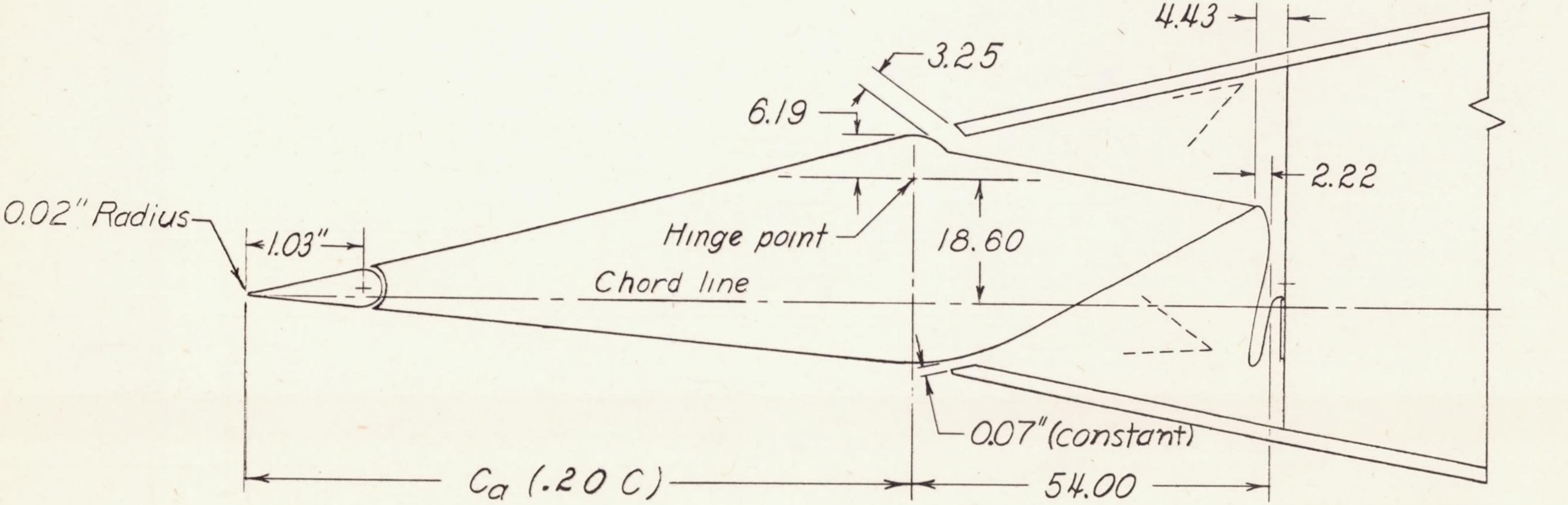

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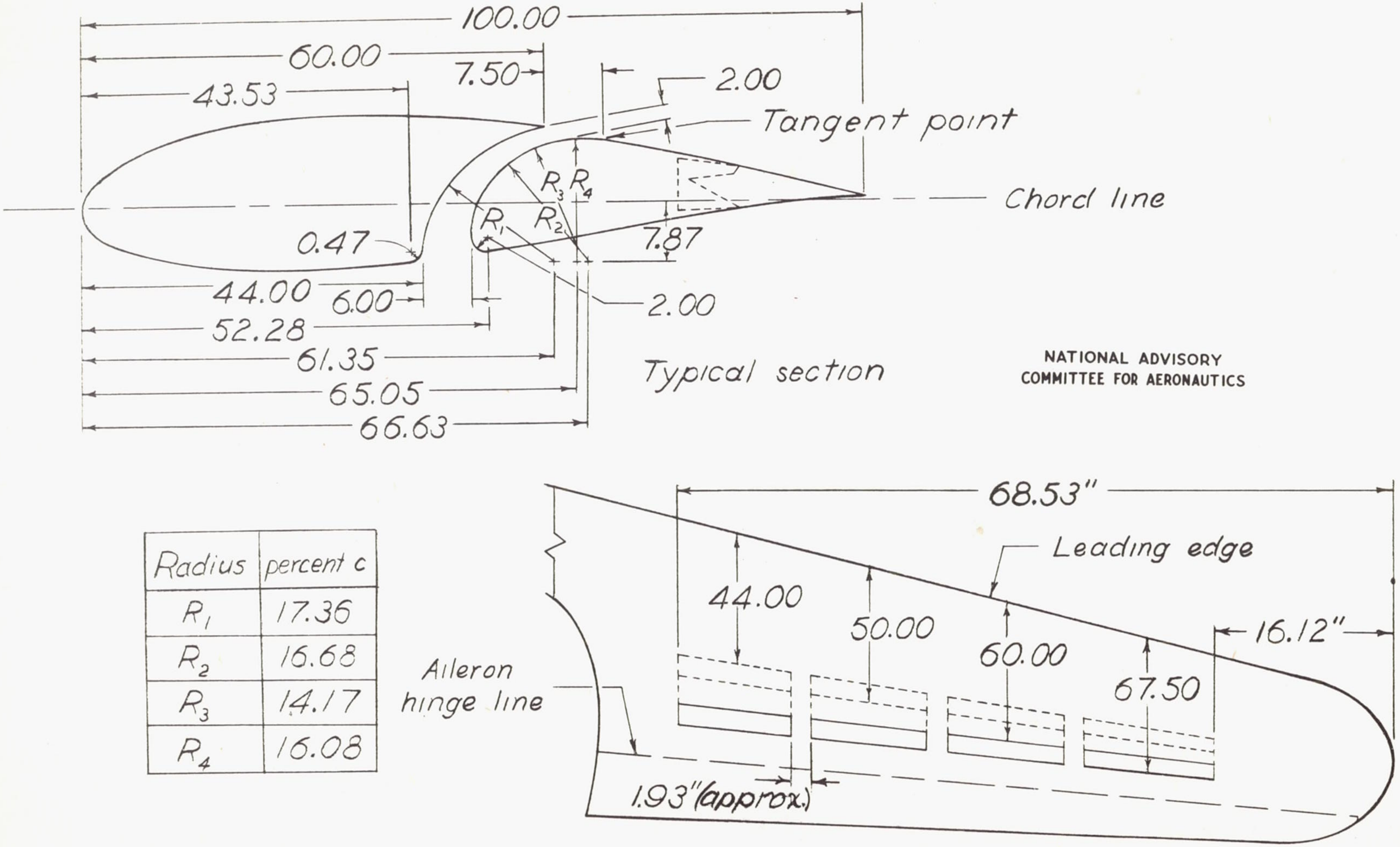
Figure 4.- Section of the aileron and tab of the partial-span wing model. (All dimensions in percent of aileron chord except as noted.)



Radius	percent c
R_1	17.36
R_2	16.68
R_3	14.17
R_4	16.08

Figure 5.- Arrangement of the midchord slot of the partial-span wing model. (Dimensions in percent of wing section chord except as noted.)

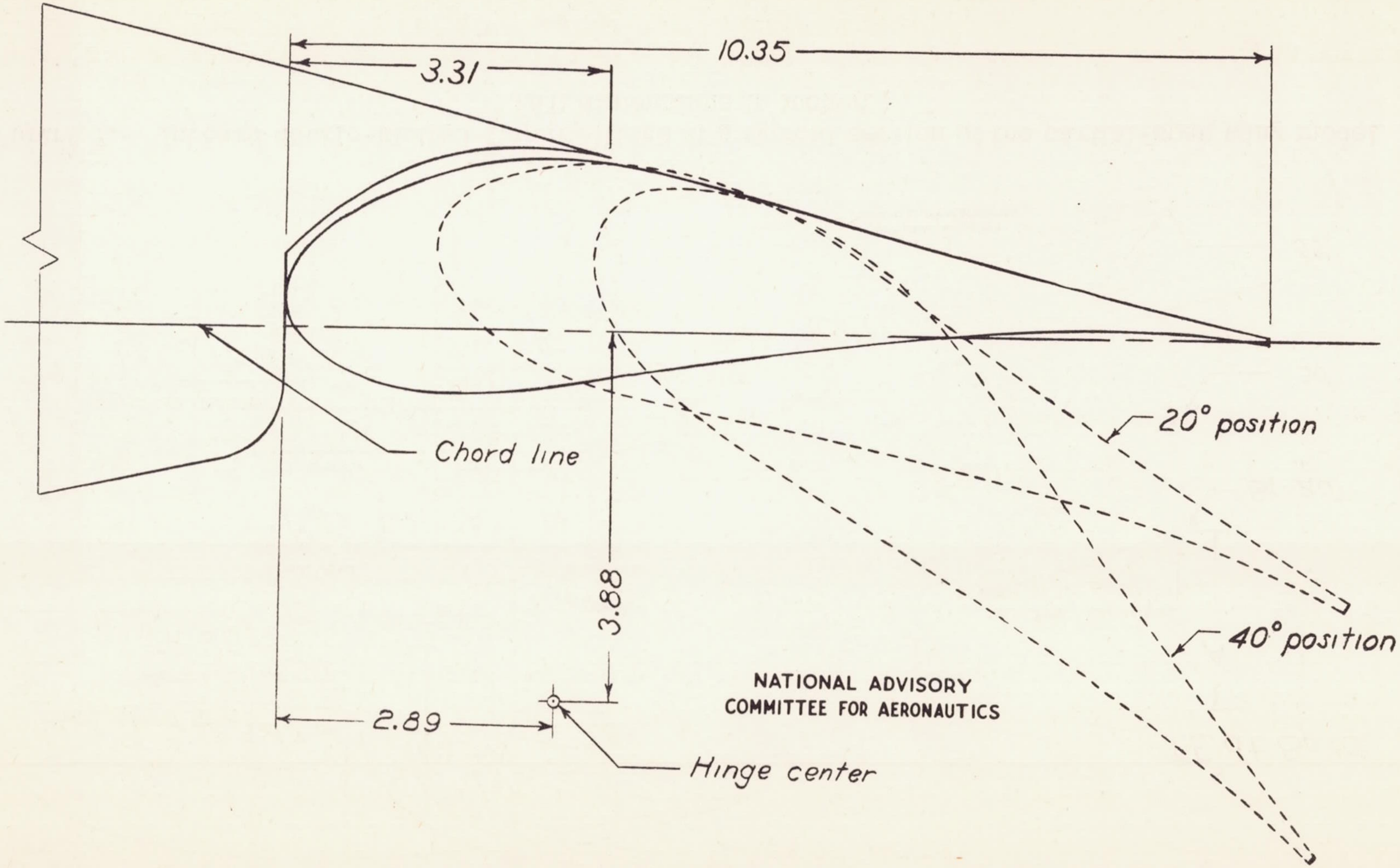
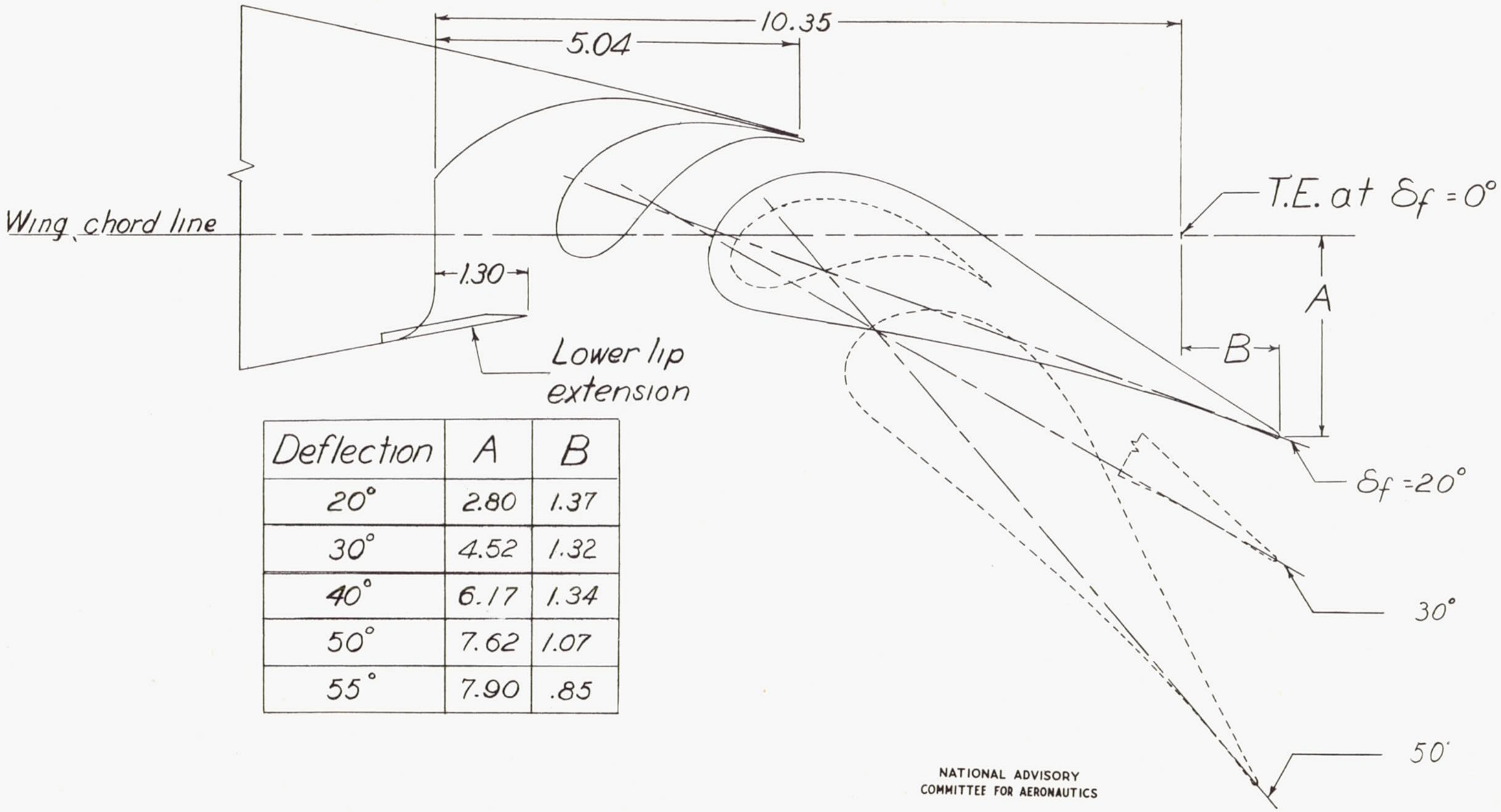


Figure 6.- Inboard single-slotted-flap positions at a typical section of the partial-span wing model. (All dimensions in inches.)



Deflection	A	B
20°	2.80	1.37
30°	4.52	1.32
40°	6.17	1.34
50°	7.62	1.07
55°	7.90	.85

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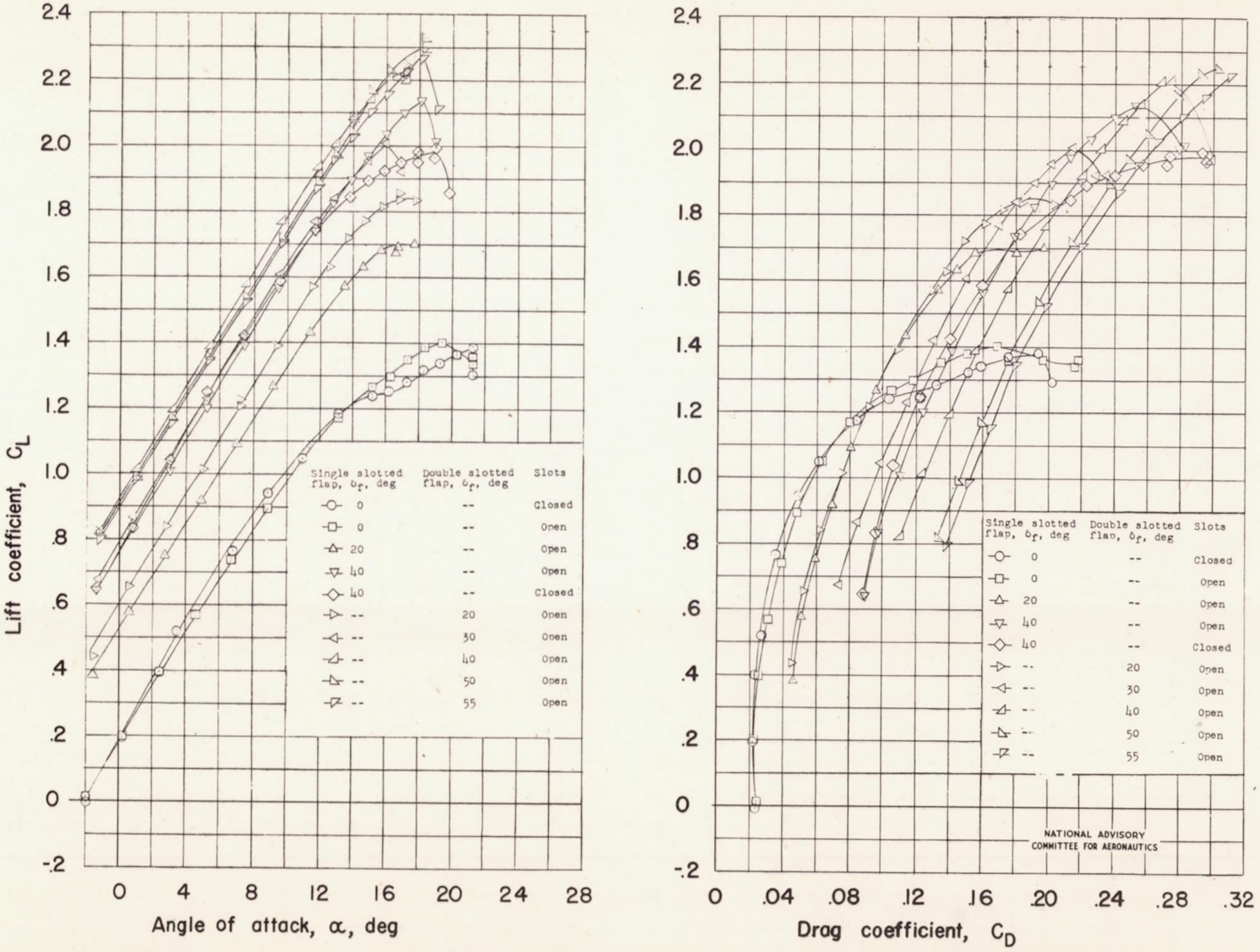
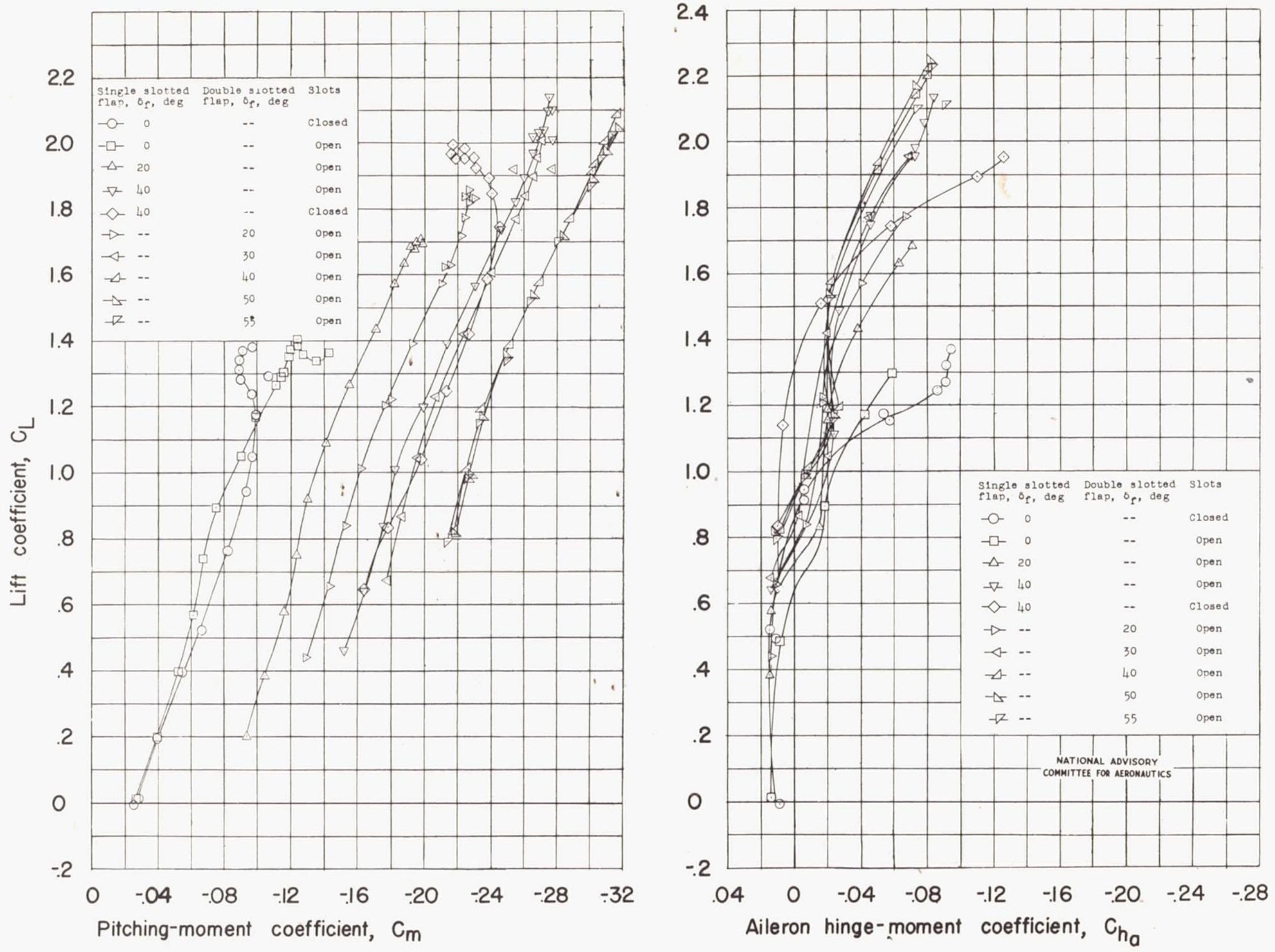
Figure 7.- Inboard double-slotted-flap positions at a typical section of the partial-span wing model. (All dimensions in inches.)



(a) Lift characteristics.

(b) Drag characteristics.

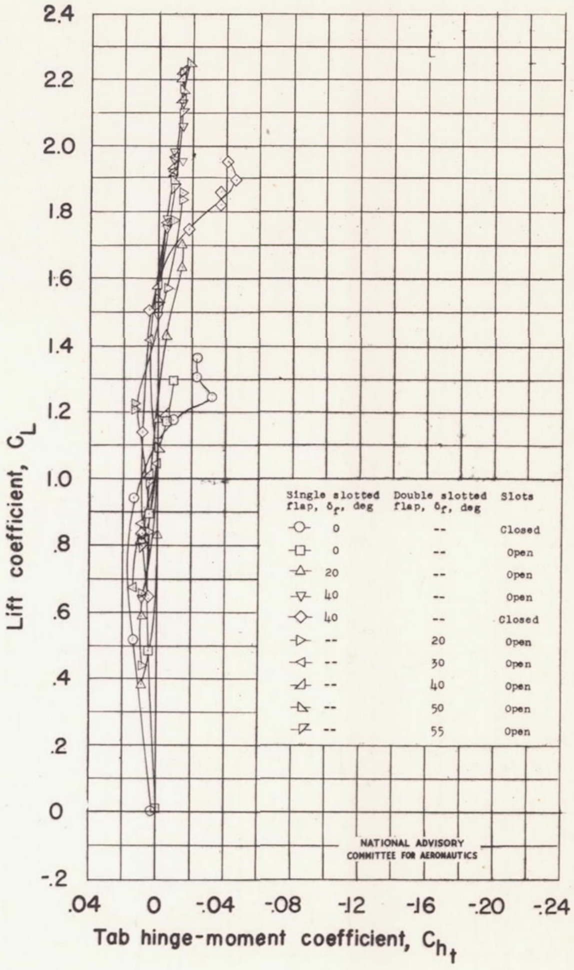
Figure 8.- Aerodynamic characteristics of the partial-span wing model with various arrangements of the flaps and slot . R ≈ 8,900,000; M ≈ 0.18.



(c) Pitching-moment characteristics.

(d) Aileron hinge-moment characteristics.

Figure 8.- Continued.



(e) Tab hinge-moment characteristics.

Figure 8.- Concluded.

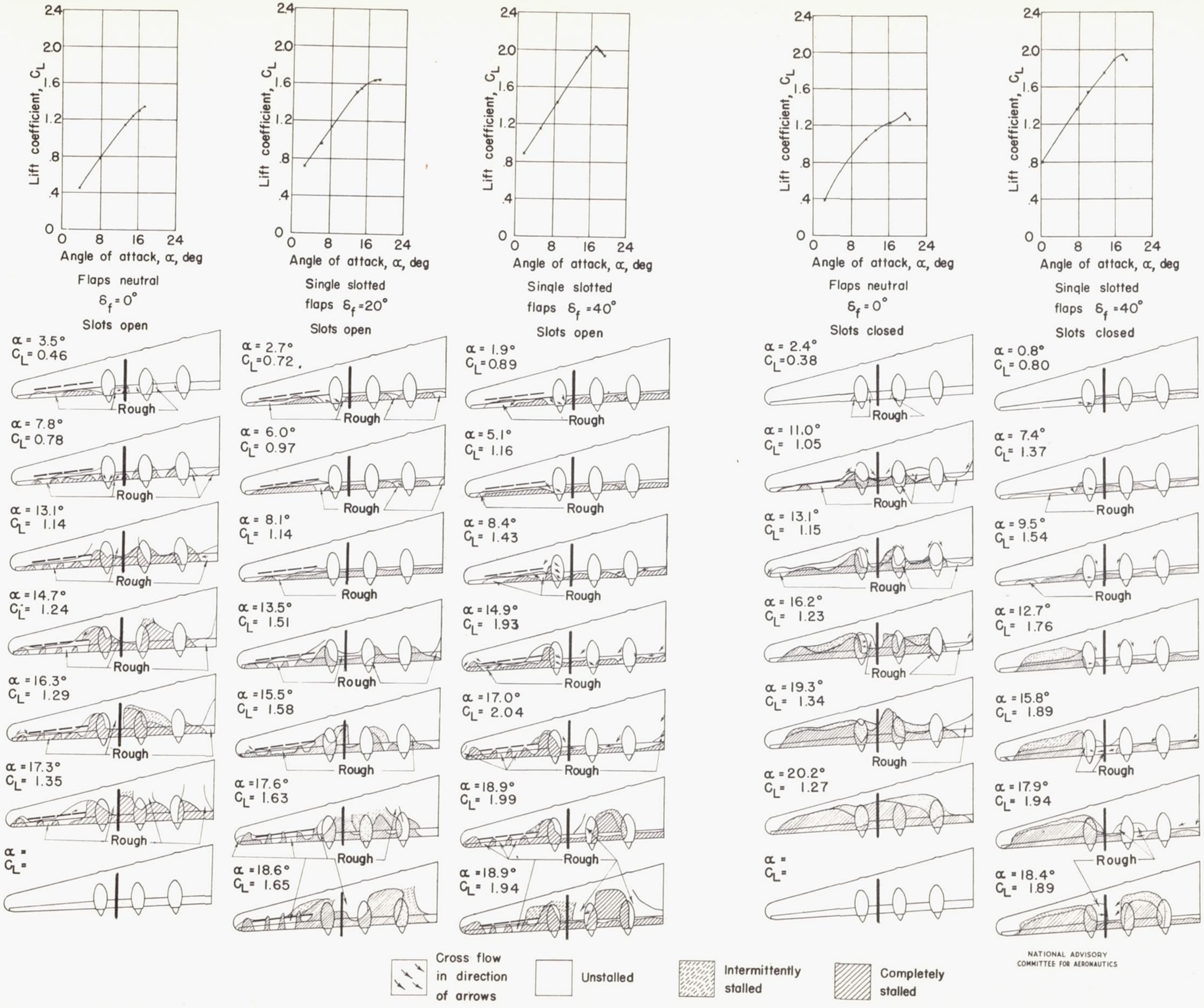
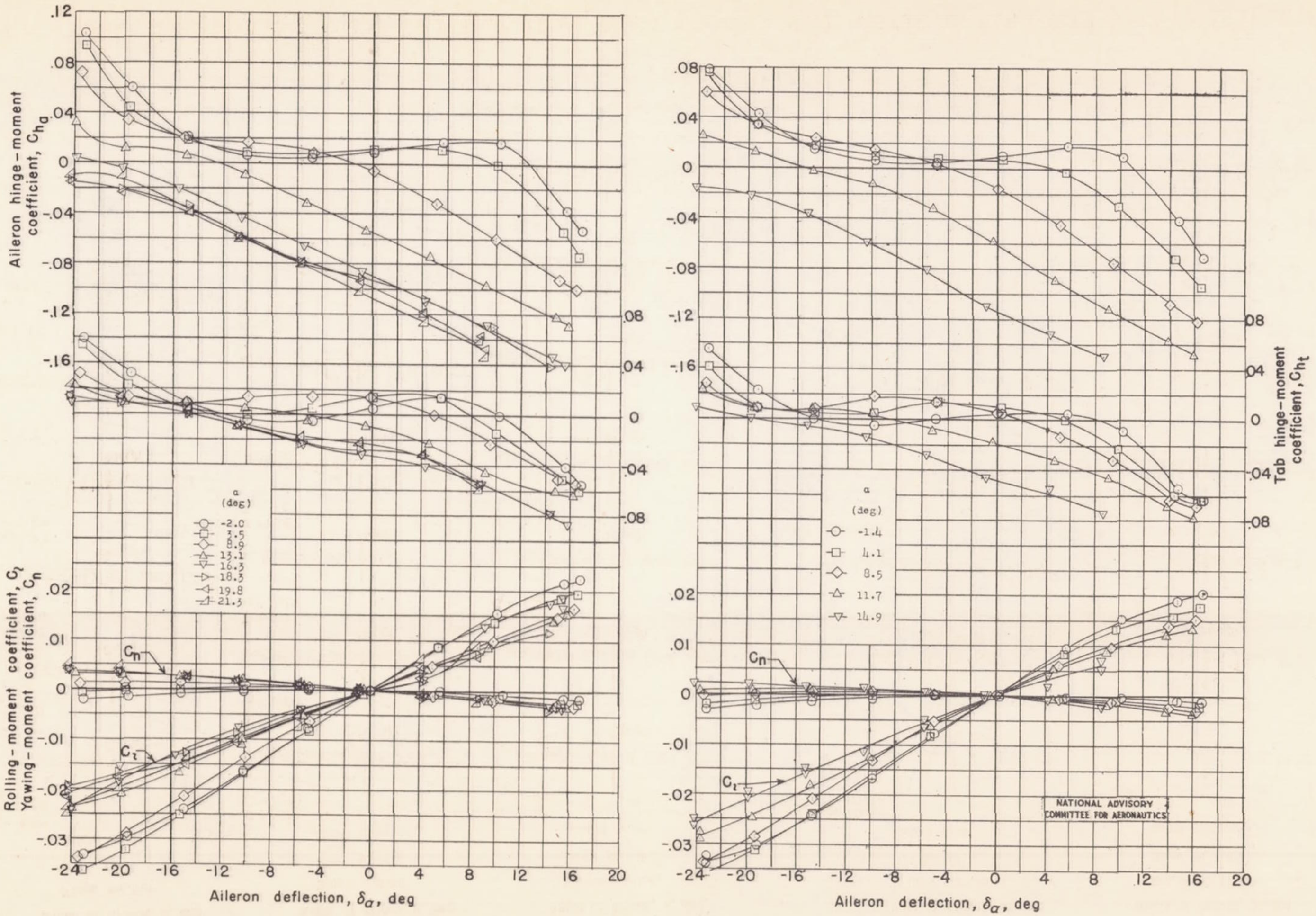


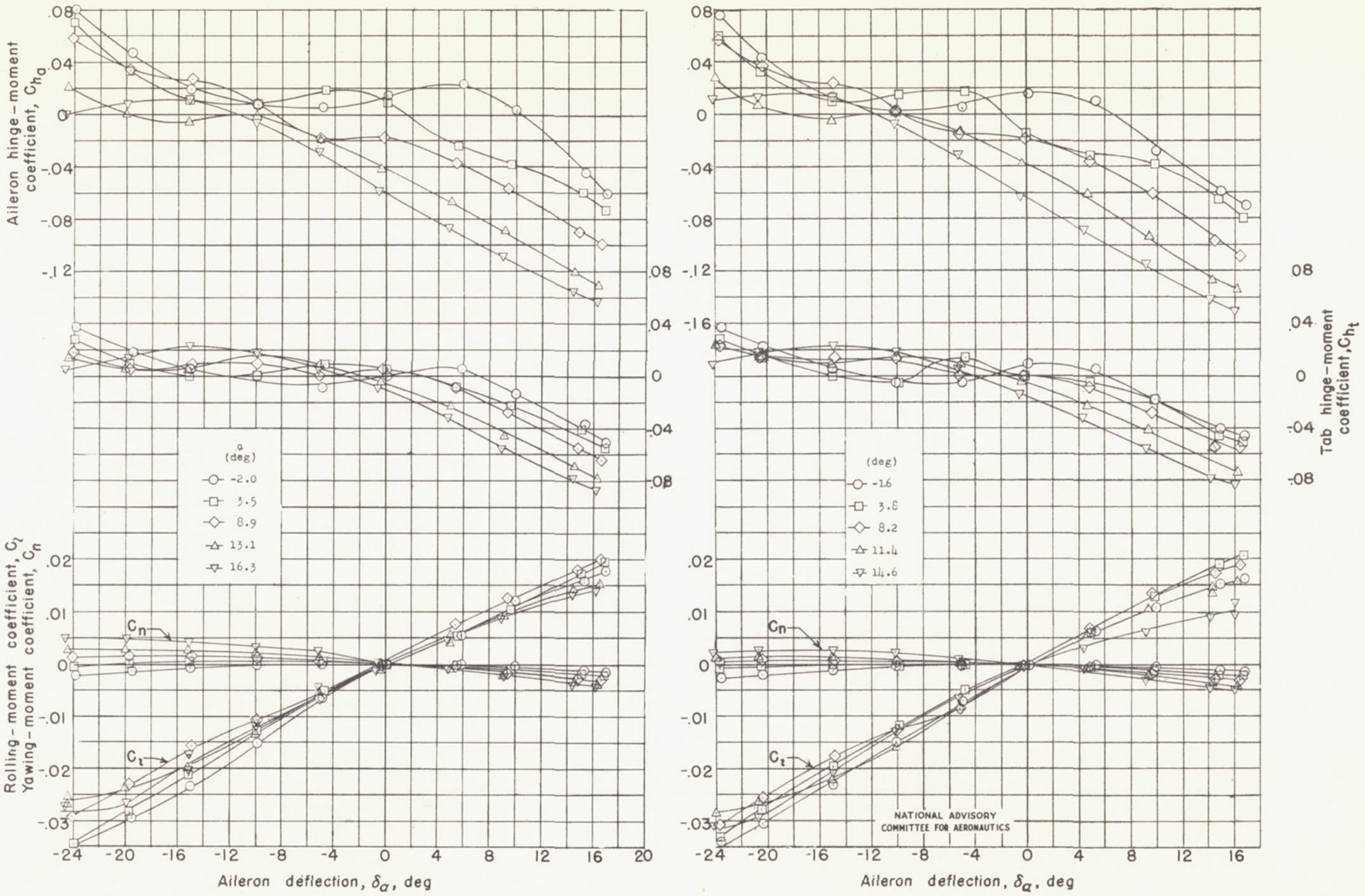
Figure 9.- Stall diagrams of the partial-span wing model with various flap and slot configurations. R ≈ 8,900,000; M ≈ 0.18.



(a) $\delta_f = 0^{\circ}$.

(b) $\delta_f = 40^{\circ}$.

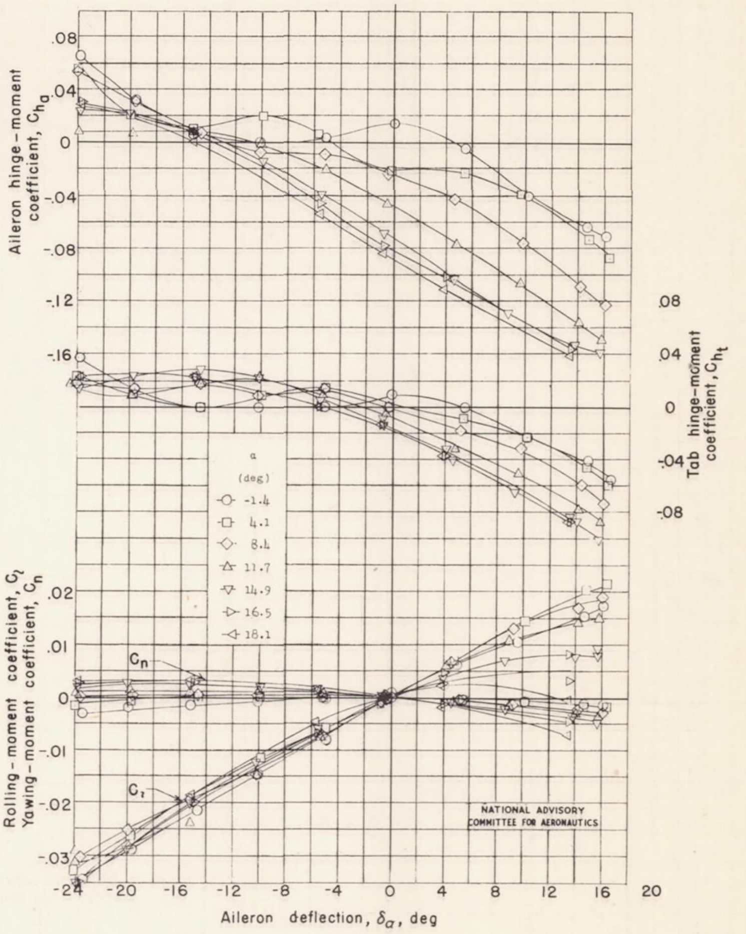
Figure 10.- Characteristics of the aileron with single slotted flaps for various angles of attack. Tabs neutral; slots closed; $R \approx 8,900,000$; $M \approx 0.18$.



(a) $\delta_f = 0^\circ$.

(b) $\delta_f = 20^\circ$.

Figure 11.- Characteristics of the aileron with single slotted flaps for various angles of attack. Tabs neutral; slots open; $R \approx 8,900,000$; $M \approx 0.18$.



(c) $\delta_f = 40^\circ$.

Figure 11.- Concluded.

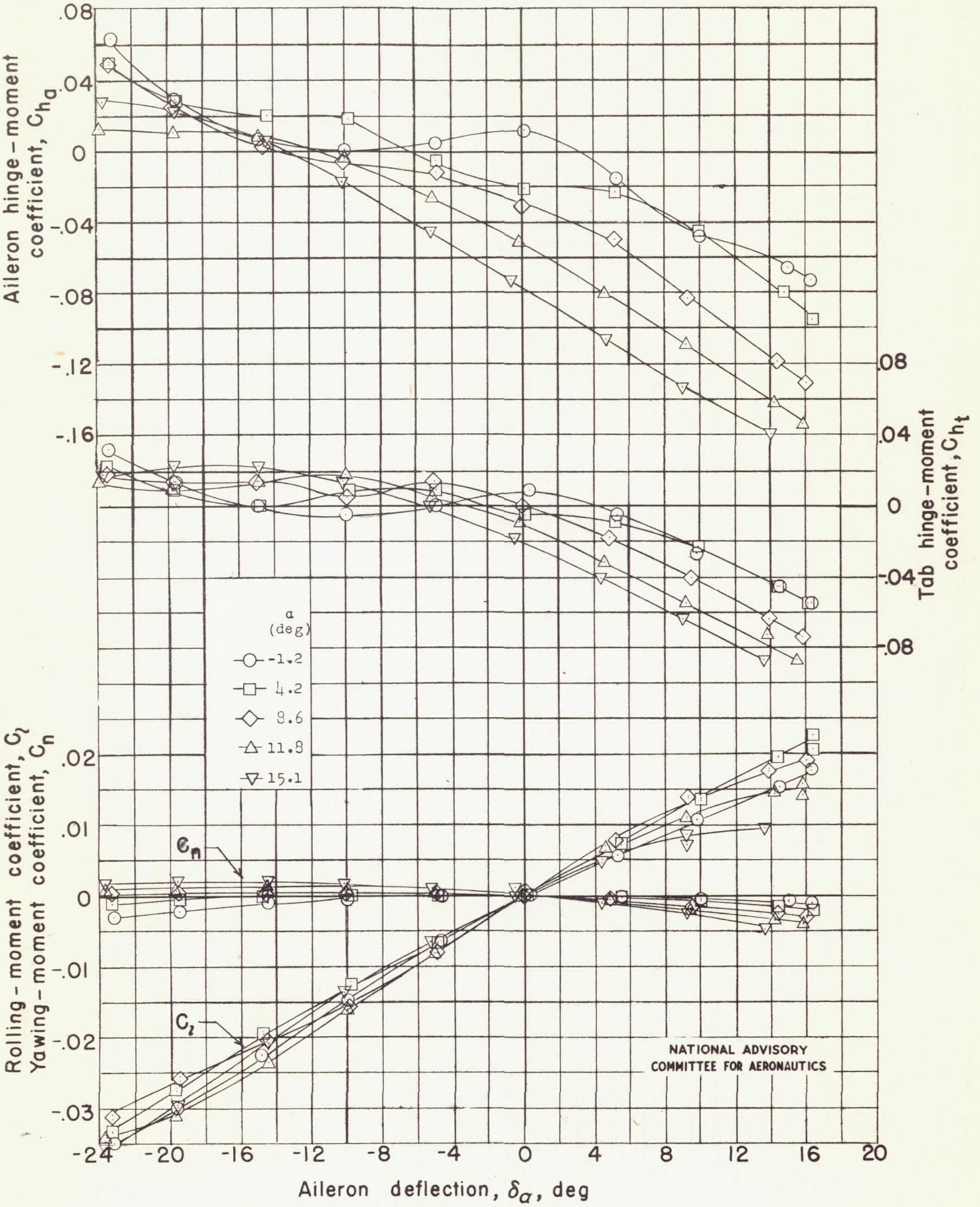
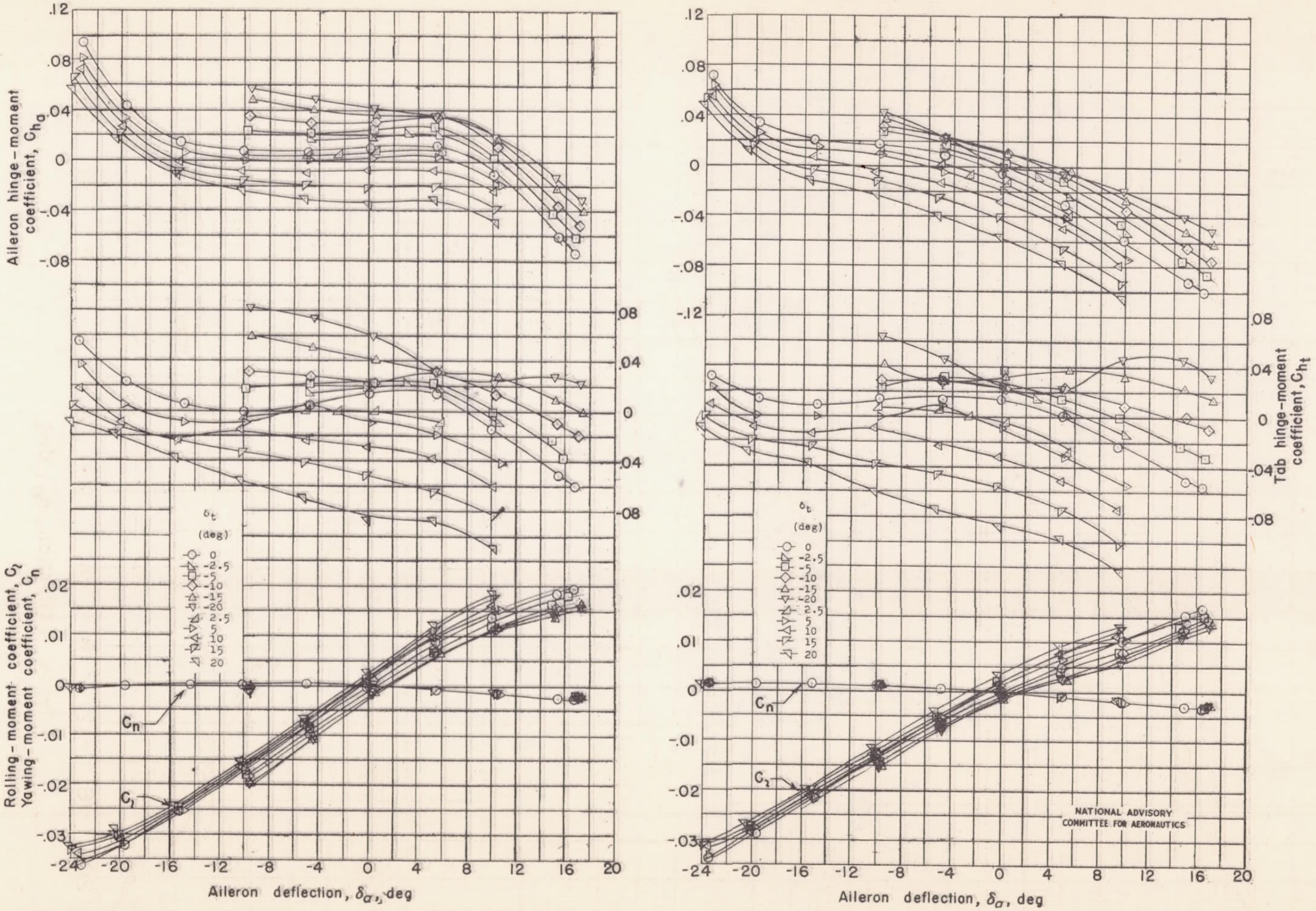


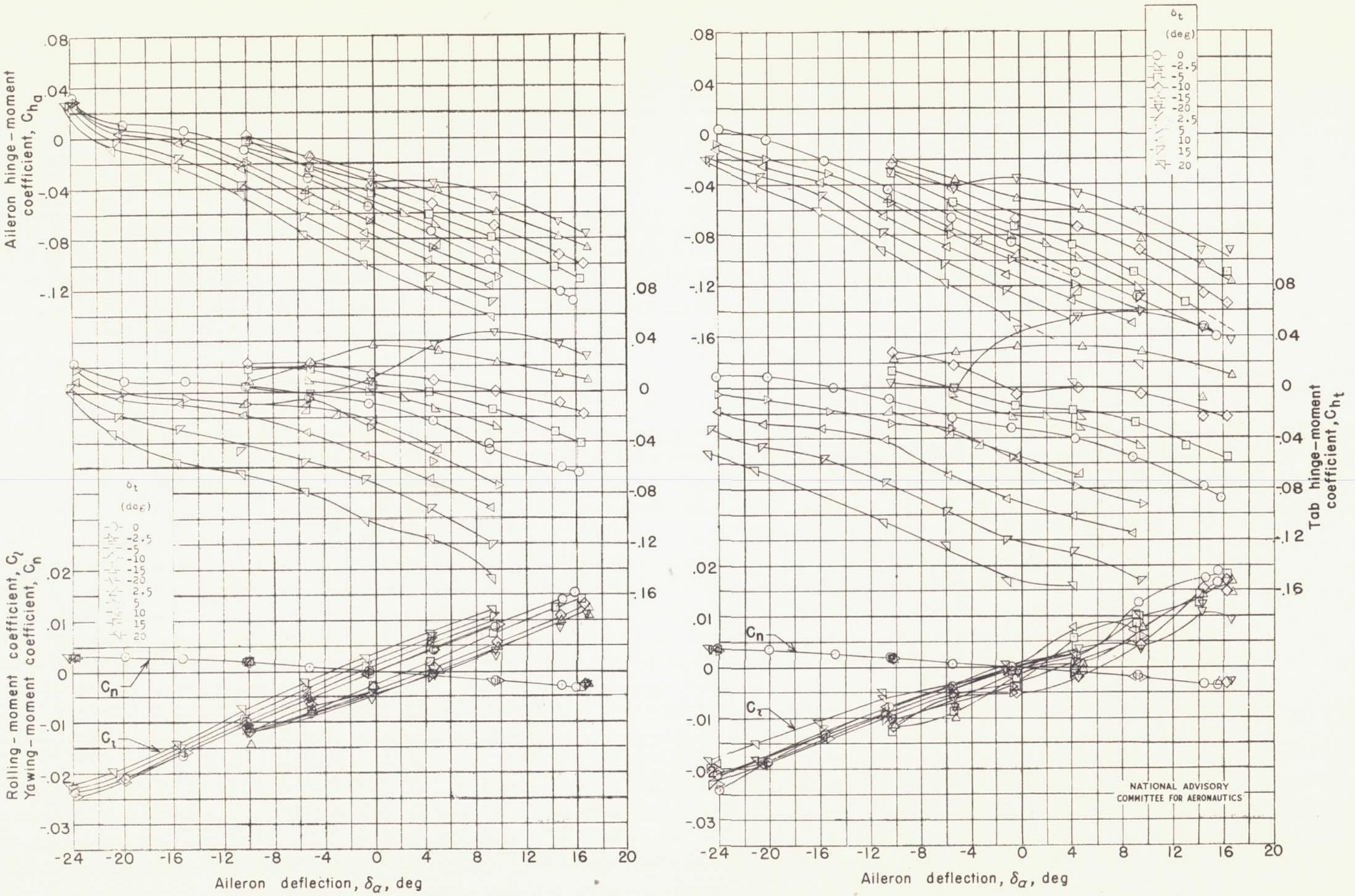
Figure 12.- Characteristics of the aileron and tab for various angles of attack. Double slotted flaps deflected 50°; slots open; R ≈ 8,900,000; M ≈ 0.18.



(a) $\alpha = 3.5^{\circ}$.

(b) $\alpha = 8.9^{\circ}$.

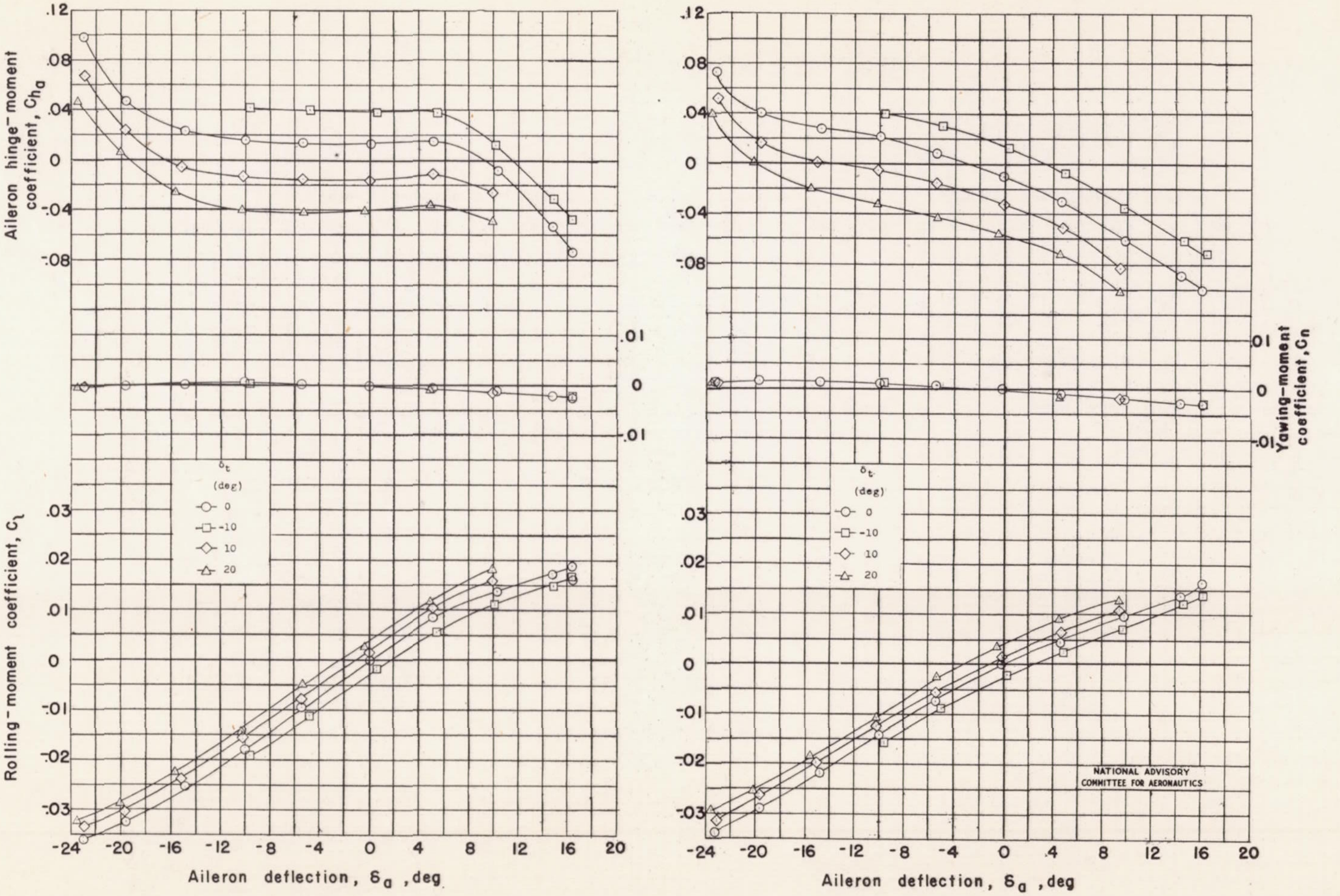
Figure 13.- Characteristics of the aileron for various deflections of the tab. Flaps neutral; slots closed; $R \approx 8,900,000$; $M \approx 0.18$.



(c) $\alpha = 13.1^{\circ}$.

(d) $\alpha = 16.3^{\circ}$.

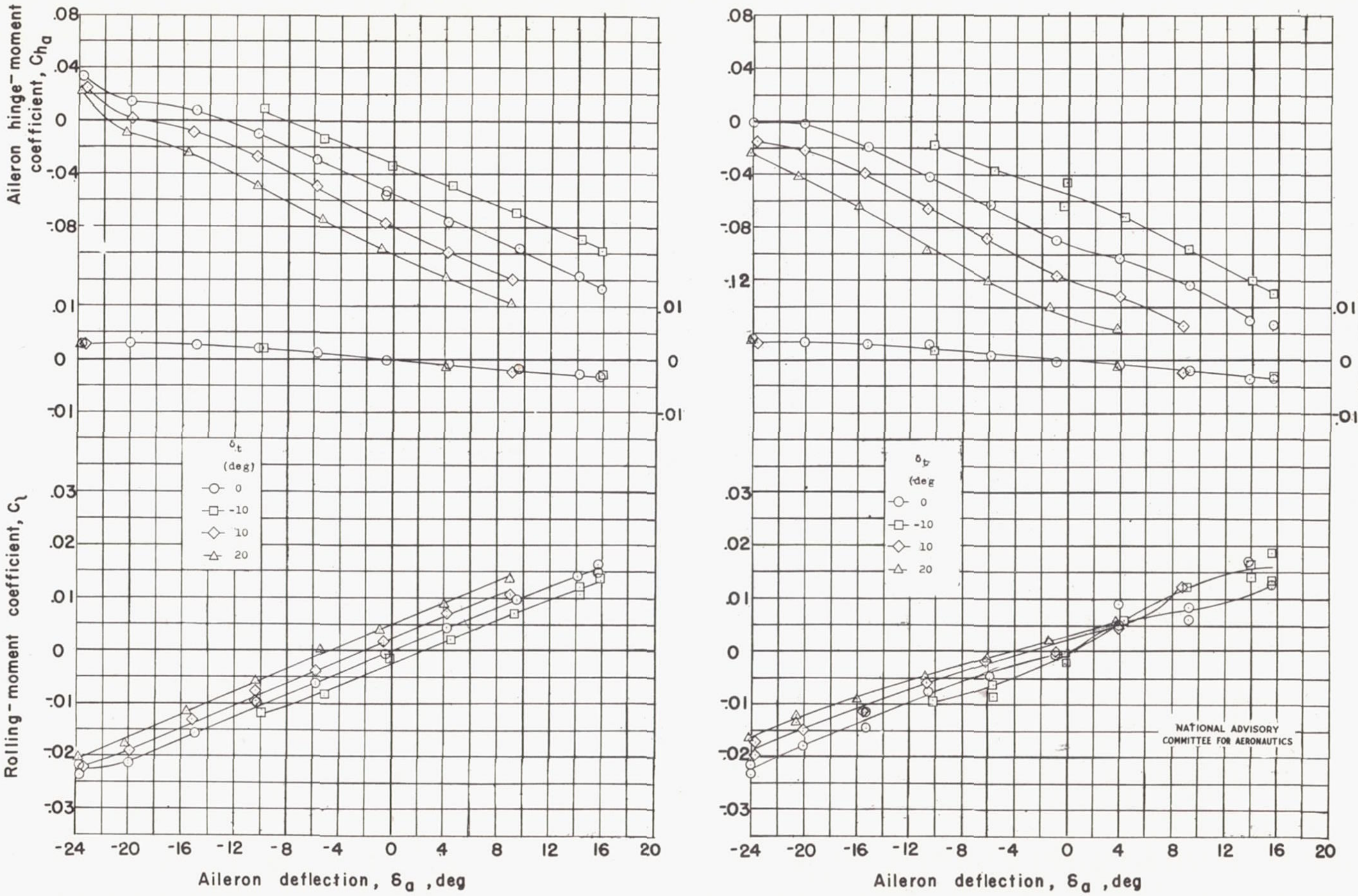
Figure 13.- Concluded.



(a) $\alpha = 3.5^\circ$.

(b) $\alpha = 8.9^\circ$.

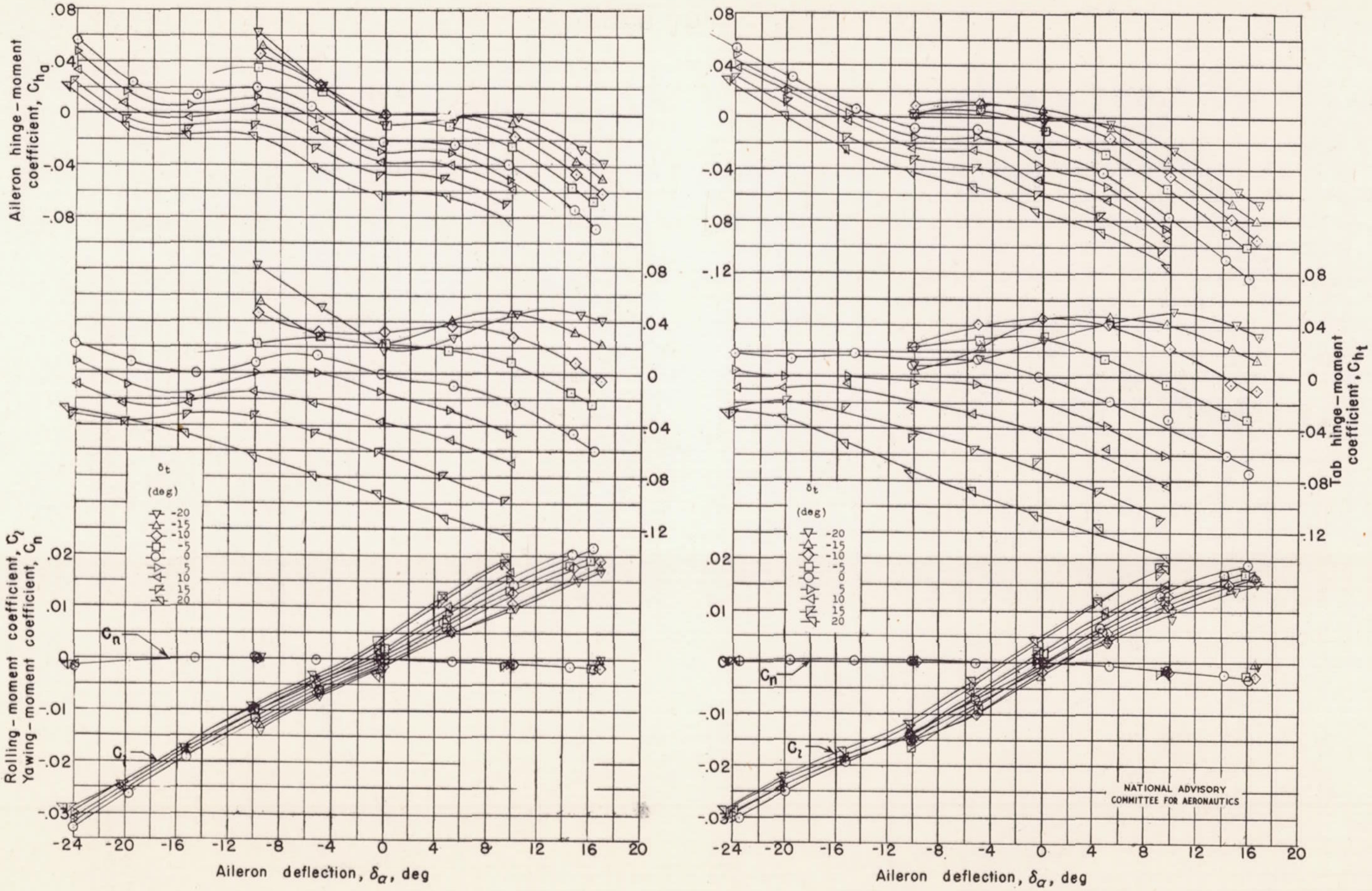
Figure 14.- Characteristics of the aileron for various deflections of the tab. Flaps neutral; tab sealed; slots closed; $R \approx 8,900,000$; $M \approx 0.18$.



(c) $\alpha = 13.1^{\circ}$.

(d) $\alpha = 16.3^{\circ}$.

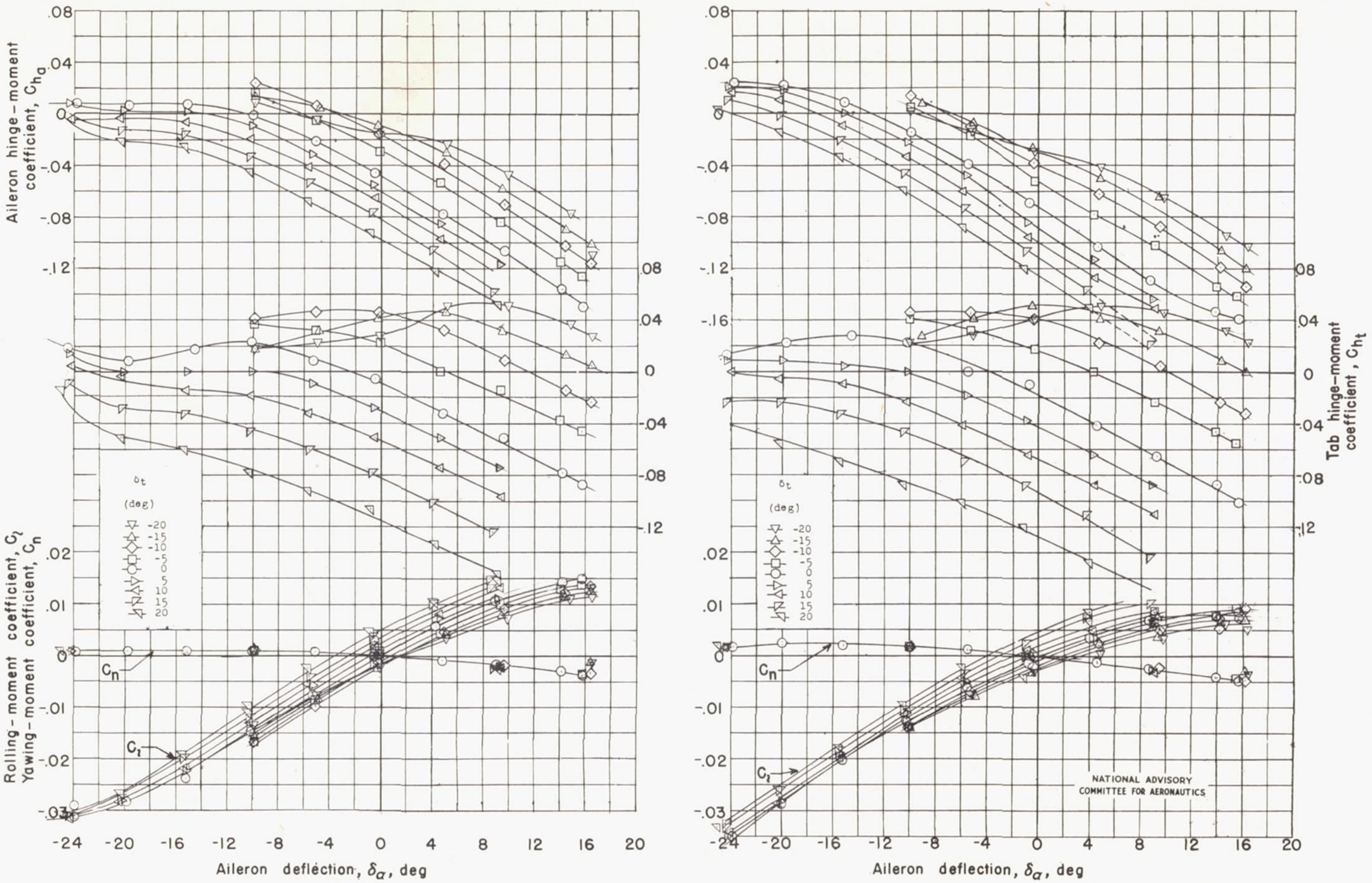
Figure 14.- Concluded.



(a) $\alpha = 4.1^{\circ}$.

(b) $\alpha = 8.4^{\circ}$.

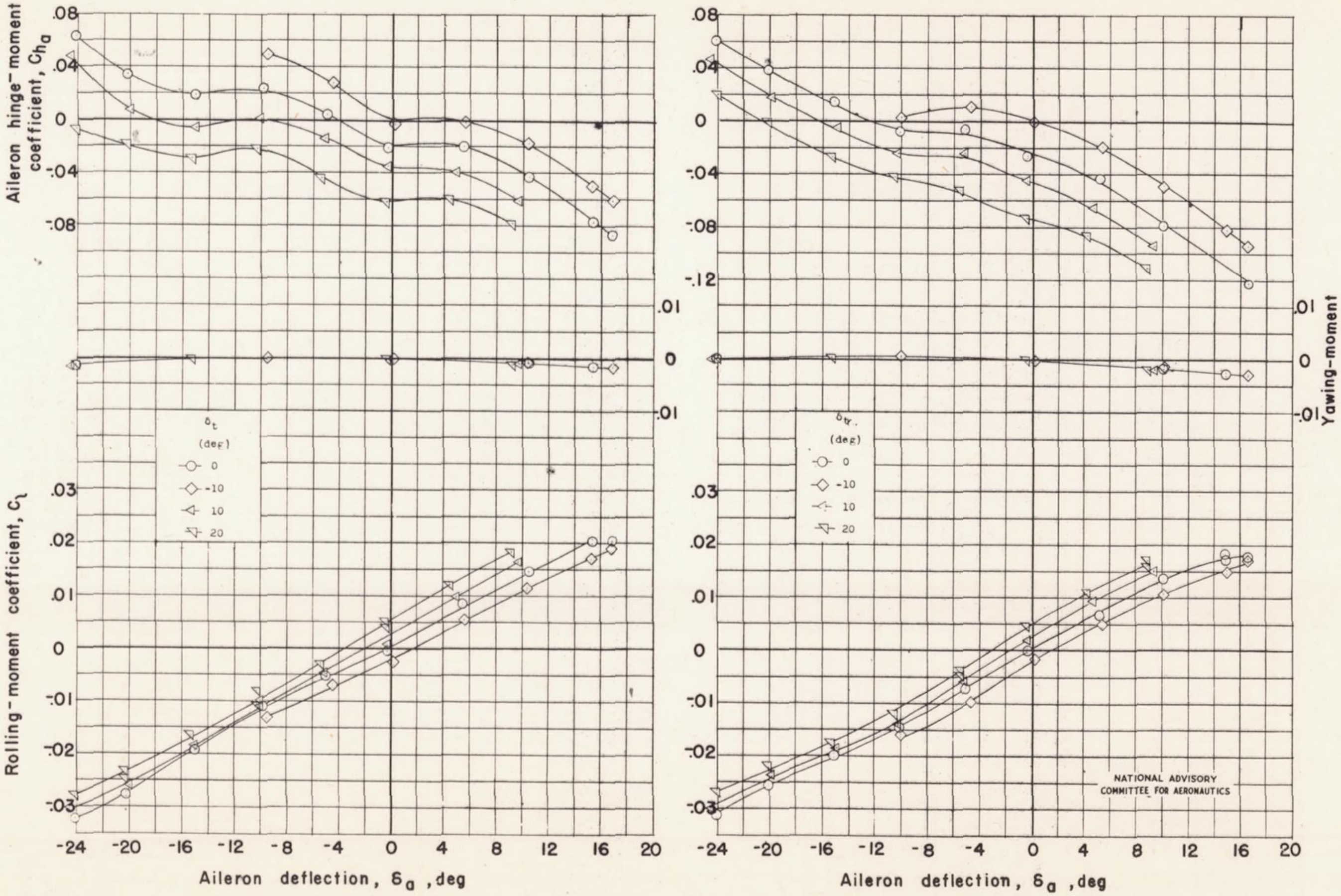
Figure 15.- Characteristics of the aileron for various deflections of the tab. Flaps deflected 40°; slots open; $R \approx 8,900,000$; $M \approx 0.18$.



(c) $\alpha = 11.7^{\circ}$.

(d) $\alpha = 14.9^{\circ}$.

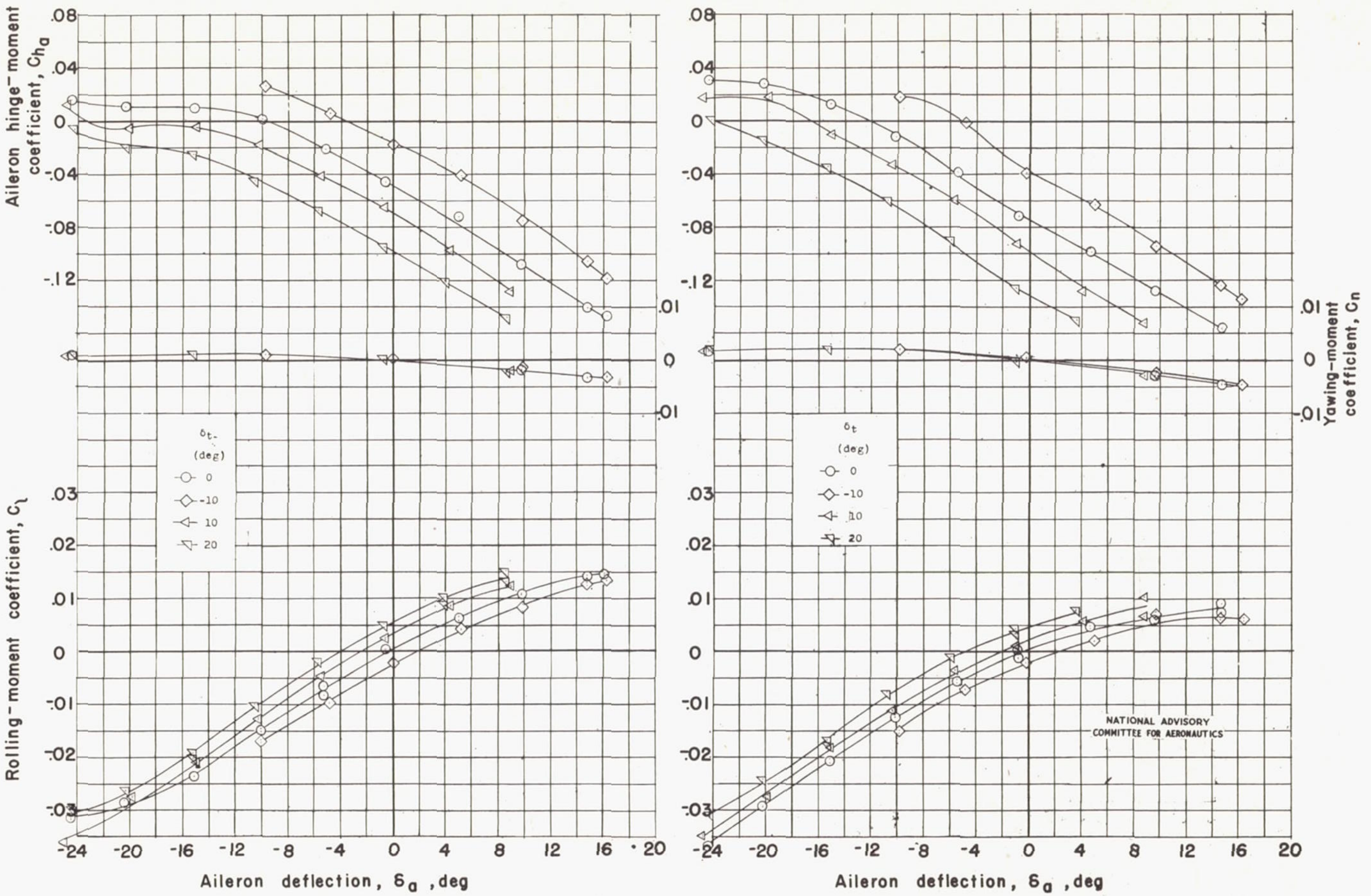
Figure 15.- Concluded.



(a) $\alpha = 4.1^{\circ}$.

(b) $\alpha = 8.4^{\circ}$.

Figure 16.- Characteristics of the aileron for various deflections of the tab. Flaps deflected 40°; slots open; $R \approx 8{,}900{,}000$; $M \approx 0.18$.



(c) $\alpha = 11.7^{\circ}$.

(d) $\alpha = 14.9^{\circ}$.

Figure 16.- Concluded.